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STRUCTURAL LEVELS IN THE SCIENTIST'S WORLD

IN dealing with the facts of nature two types of explanation are exhibited by science. In the first an event is explained by referring it to a general law of which it appears as a particular instance. Such laws are gleaned from a classification and comparison of instances, and represent generalizations that have been tested by their power to enable us to make verifiable predictions. The second type proceeds by showing us that the situation in question is a consequence of the lawful behavior of more elementary facts out of which it is constituted. That is, there is presupposed a group of general laws characterizing the behavior of certain entities which can become organized into groups constituting the facts of which an explanation is sought. An example of the first type of law is the formula of gravitation, that all matter attracts all other matter with a force proportional to the product of the masses divided by the square of the distances, for this merely serves as a generalization under which falling bodies and the motion of the planets can be subsumed as particular instances. The second type can be illustrated by the explanation of the behavior of a chemical compound through the nature and valencies of the atoms of which it is composed, or of the behavior of a mob through the natural tendencies of the individuals in it, when these tendencies are heightened or suppressed by the reactions of the individuals on each other as well as on the situation toward which the mob activities are directed.

The second type of explanation is dependent upon an analysis of the world into classes of entities which for our present purpose can be designated as levels. Thus in the present state of physical science we can distinguish four principal levels: the electronic, the atomic, the molecular, and a level consisting of aggregates of molecules, whether solid, liquid, or gaseous. Ether is not here included as a level, for at present there seems to be no fact of observation or theory that demands the hypothesis of the disintegration or disappearance of electrons, though Planck's quanta theory, with its suggestion of energy atoms, may lead us to a granular conception of the ether and, with it, to a need of relating the electron to these granules. Until further developments have taken place along this line, while there can be little doubt that the ether concept represents something physically real, ether remains an hypothetical connecting medium by which certain types of motion are communicated from one body to another. Its inclusion or exclusion, as a level, however, would not affect the general results at which our analysis arrives.

The electronic level of entities can obviously only be understood in terms of general laws descriptive of the behavior of electrons at present. On the atomic level, however, further results are obtainable. Since Dalton, in 1801, hit upon that transformation of the atomic theory that gave it genuinely quantitative character, the study of atomic weights and their arrangement by Newlands (1863) under the "law of octaves," and the correlation of properties as periodic functions of atomic weights by Mendeleef (1869) have opened up previously unexpected fields. If properties are correlated with weight, the suggestion at least is strong that they are consequences of structure, and the evidences obtained from Crookes's fractionations of yttria (1837), the Zeeman effect (1898), Lockyer's analysis of star spectra (1900), J. J. Thompson's studies on the conductivity of gases (1904), and Soddy's interpretation of radium (1909) give almost overwhelming evidence that such complexity is actually a fact. If electrons are here the constitutive element, it must be the ideal of the chemist to account for the properties of atoms as consequences of an organization or integration of the electrons by which they are constituted. Even prior to the knowledge of electrons, Crookes (1886) proposed his pendulum oscillations hypothesis concerning the mode of genesis of the atoms from an interior element named *protyle,* and since the recent growth of knowledge concerning the relation of electricity and matter, speculative explanations of valency and other atomic properties have begun to appear.[1] In particular, J. J. Thompson (1904) has assumed atoms composed of varying numbers of corpuscles and in forms conditioned by the demands of stability for various numbers, by means of which he suggests explanations for the recurrence of similar properties exhibited by atoms of increasing weight, the differences in their electro-chemical nature, in their valencies, and the tendency to chemical combination between the different kinds.

While the above researches must still be held to be of a somewhat speculative nature, they are nevertheless indicative of a tendency of science. Between higher levels examples could be multiplied: for example, the creation of stereo-chemistry to supplement, in cases of isomerism, the explanation of certain molecules in terms of their constituent atoms, and studies of the behavior of the surface molecules of liquids to explain surface tensions, capillarity, etc. Indeed, the modern chemist is already working on the basis of a pretty clearly defined concept of levels and his ideal may also be seen in physiology and in all modern biological study of the process of growth, heredity, transmission, and the like.

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[1] Cf. Freund, "Theory of Chemical Composition," Ch. XIX.

Each level of the physical world, above the electronic, is then to be looked upon as containing entities constituted by an integration of entities on a lower level in accordance with the lawful forms of their behavior. But it is to be noted that the consequent behavior of these aggregates is not the behavior of the elements of which they are composed: electrons do not have valency, atoms have not molecular properties, and, for the molecule, surface tension or the solid, liquid, and gaseous states are meaningless. Even when a property seems to be present on several levels, as a mutual attraction between entities, its description is markedly different in the different cases, as was the case in the now outlived "distance coefficient" physics.[2]

If the rise from the simplest to the most complex level is looked upon as a process taking place in time, it would appear that the world is a place where novelties, at least in the sense of facts requiring new and previously meaningless types of description, are constantly arising. To conclude that this is the sole course of events, however, is somewhat hasty, for, if we are to accept Lockyer's conclusions from the analysis of stellar spectra, it would appear that there are stars growing hotter as well as stars growing cooler, that is, stars in which the atomic elements are in the process of disintegration as well as stars in which they are being formed. In other words, it would appear that with sufficient cooling so many heavy atoms are formed that radioactive processes set in which reverse the course of development and lead to general disintegration, which must, in some manner, be reversed when the free electrons are again obtained.[3] Thus a cyclic type of process would be indicated and, as this process is characteristic of each star, the change in the whole universe can perhaps best be described as maintaining a statistical identity. Carnot's principle, however, if valid without restriction, introduces further complications the discussion of which now would lead us too far afield.[4] We are here close to the borderland of scientific speculation and must wait further knowledge to solve the problem of cosmology.

The point that concerns the philosopher primarily is the interpretation of the nature and extent of the novelty that appears at each change from a lower level to a higher in specific cosmic integrations. The final test of a scientific principle is the verifying predictions that can be made by it and, while the present state of our knowledge leaves far too many gaps, there seems to be a body of ever-increasing evidence that, given knowledge of the laws of behavior of the entities on any one level, it is possible to predict the character and behavior of entities on the next higher level that are constituted by an integration of the elements of the lower level.

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[2] Poincaré, "The Foundations of Science," page 298.

[3] Lockyer, "Inorganic Evolution."

[4] Cf. Poincaré, *loc. cit.*, pages 303–5.

If our evidence was merely in the physical sciences, however, it would not be so cogent, for it could be argued that, inasmuch as a knowledge of the lower levels is obtained from analysis of the higher, there must, *a priori,* be introduced among the properties of entities on a lower level all of those characteristics which would be necessary to account for properties found in the higher. But, fortunately, the principle of levels is not limited merely to the physical world. The multi-molecule[5] of the physiological chemist, the protobion of the biologist, together with his cell, organism, and multi-organism all represent similar structure, and these things are not, for the most part, entities, knowledge of which is derived from the study of the wholes which they constitute, but entities, the knowledge of which is attained from direct contactual study.

If it were to be assumed—a thing which seems contrary to probability as our knowledge now stands[6]—that the physical universe once consisted solely of free electrons, it is theoretically possible that the evolution of matter, plants, and animals might have been predicted, but it would be a mistake, of a type to which philosophers are only too prone, to assume that therefore the laws of electronic action are the supreme laws of the universe in terms of which all its happenings should eventually be construed, for such prediction would have to take the form of predicting first the integration of electrons into atoms and the consequent laws of atomic action, then the integration of atoms into molecules and their consequent properties, etc., and at every step the new types of law appearing would be as genuinely and as profoundly of cosmic significance as the fundamental laws from which a start was made. Atoms do possess affinity, masses gravitate, and men love just as truly as if these acts were not resolvable into consequences of their several structural characteristics. To make any one of these things supreme is merely to indicate an interest, historical, logical, esthetic, moral, or the like, and so, perhaps, to record a fact of one's personality concerning which the affairs of the universe, as a whole, are sublimely indifferent.

In so far as descriptive characteristics are concerned, then, from the point of view of simpler levels, each more complex one presents genuine novelties, but novelties rationally connected with them inasmuch as they are predictable consequences of their laws. They are novelties, however, because no genuine whole is merely the sum of its parts, but is a consequence of the integration of its parts, and such integration is not, in general, expressible entirely in terms of the parts and their relations. Because picking a pocket involves movements of physical masses at varying velocities and therefore could be studied from the point of view of mechanics, and chemical and organic processes that might make it of interest to the chemist or the physiologist, it does not follow that it is not also a real fact for the student of human conduct from a social point of view and that for him it may not constitute an event the significance of which can not be expressed in terms of the sciences previously mentioned. Also the reaction of any integrated group or whole to any other such group is something quite different from the reactions of any of their constituents to each other or from any fact that can be expressed in terms of such reactions.

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[5] Moore, "Origin and Nature of Life," page 129.

[6] Cf. Lockyer, *loc. cit.*

If, then, one were to give a classification of sciences from a philosophic point of view, it would be necessary to abandon the accidental divisions that have their origin in the "sports" of history. There would be, in the first place, a group of sciences each of which should concern itself with the descriptive laws of entities on each level of integration, and each such science, if ideally developed, should be able to show how its entities could become integrated into those of the next higher level of complexity and furnish the explanation of the laws discoverable on that level. To these would be added a methodological science, or formal logic, which should abstract from concretely discovered relations the types of those relations and by developing these abstractions furnish a useful instrument for the study of the concrete facts from which they are derived. We have such a logic in mathematics, and, under the special form of "pure mathematics," a still further refinement in which abstraction leads us beyond the limitations of physical fact so that the earlier form of mathematics becomes for it an object of study which it can aid in developing, and beside the facts of nature, it also includes such facts of concept relations as are expressible in the algebra of logic. It is hardly necessary to recall the value of such sciences to the physicist and if, as yet, they seem to have done little for social science, it may be either because the fundamental laws of social sciences are not yet sufficiently clearly grasped, or because the complexity of social facts is such that a calculus would be too complex to be convenient, or most probably, because man's place in nature is such that the concrete actuality has for him an importance that makes impracticable the neglect of detail that everywhere enters into the physicist's generalities. In calculating the trajectory of a shell from a gun, it may not be important to note that every particle of matter in the universe attracts every other particle, if it does, with a force proportionate to the product of the masses and the square of the distance, but it does not follow that a similar simplification is possible in studying human conduct. H. G. Wells says somewhere, that if we could take men by the ten million they would be as alike as atoms, and if we could take atoms individually they would be as different as our uncles and cousins—a suggestion gaining support through recent investigations —but our place in nature makes the one generalization of supreme importance and the other of no value at all.

One further comment should also be added concerning the methodological science. Although its fundamental facts are concrete relations, the results of generalizing them do not imply physical structure corresponding, unless the group of premises are together concretely verifiable in fact. It is perfectly possible to state a mathematical physics that should have no meaning in any world in which man has ever lived. Neglect of this fact has precipitated philosophers into that meaningless dialectic of infinity which has made their cosmologies for the most part valueless budgets of paradoxes. An infinity of concrete entities has never been found by any man and, from the nature of the concept of infinity, we can say *a priori* that it never can be. The extent of space or time is an empirical question that can only be answered, if at all, by observational and not by theoretical methods. In other words, mathematics can only extend our knowledge of nature by elaborating relations already observed and so leading us to new observations and verifications, but can not give any guarantee that its abstractly formed structures shall have factual counterpart when the elements for its syntheses are "freely chosen."

Scientists must get their results as best they can, and in suggesting the above principle for the classification of sciences it is not meant to introduce a revolutionary nomenclature that might possibly be more confusing than helpful. The specializations of physical sciences conform fairly well to the principle enunciated. The study of electricity is primarily concerned with electronic phenomena; the chemist concerns himself with atoms and molecules; and the physicist with integrated groups of molecules. In biology, too, our leading idea is found. Colloidal substances give rise to unicellular organisms, from these multicellular organisms develop, and the concept of the multi-organism seems to be making its way.

In psychology and the social sciences, however, the situation is not satisfactory. There is a place for the study of the laws of the behavior of organisms and multi-organisms and the explanation of their laws through the laws of their constituent elements. Such a science would do for the animate world what physics does for the inanimate and might be called organic physics as parallel to the inorganic physics now familiar. Behaviorist psychology is the branch of this science that restricts itself to animal, including human, behavior, as plant physiology nearly covers the remaining field of this physics of the animate. The study of the human being as a special object here has for us peculiar importance and immediacy, and the introspectionist psychology tries to introduce consciousness as a new level of entity, but is in constant confusion because the behavior which should be explained through the nature of this entity is constantly getting explained by organic conditions and the entity is forced into the unique position of being constituted by nothing and explaining nothing until it becomes described as a "double aspect" or "epiphenomenon" and neglected as much as possible in all practical work. The difficulty lies fundamentally in ignoring the nature of levels, for these conscious entities are really nothing but integrations of physical states and organic processes.[7] Behavioristic psychology is winning the field not so much through a dialectic refutation of the claims of the introspectionists as through a progressive solution of problems that remained for it insoluble. A grin without the cat may be interesting, but it is much more interesting if the actual cat laughs when tickled.

When we come to the social sciences the situation is also confused. There are integrated groups of men, as well as animals, that react on each other and on their environment as a new order of entities and require the independent statement of their laws as such. But just as the behavior of the atoms within a molecule is not the behavior of free atoms, so the behavior of men in such groups is not the behavior of men outside of those groups. The behavior of the constituent elements is, however, expressible in terms of the laws of those elements, while the behavior of the group is not. No one would attempt to express the properties of a molecule by the same laws that describe the behavior of atoms, yet in social science there are frequent attempts made to express the character of group action in terms of psychological law, or the laws of the action of the individuals out of which the group is constituted, and, I believe, a clear consciousness of the difference involved might clear the way for progress. Our place in nature, however, suggests that the study of individuals as restricted by participation in group entities may be vastly more important than the studies of the groups themselves, that is, the materials for the explanation of the group laws may be at least as important as the laws of the group that are explained. s

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[7] Professor Holt in "The Freudian Wish," Ch. II, seems to be the only psychologist to have grasped the fact that new entities can be constituted through the "integration" of simpler ones.

A further division of psychology and social science is also suggested by a certain peculiarity in human behavior. If the rationality of man means that "the development of his nervous system holds his responses in check so that when he does act, he acts as a creature who has had experience and profited by it,"[8] rationality of conduct implies a new study in which ideas as ideals furnish the subject-matter. Human behavior is then studied, not merely for the sake of knowing what it is, but what it ought to be and the so-called normative sciences are born. Thus through perspective we find the study of facts nearest to us leads to significant subdivisions of certain levels that are not paralleled in dealing with physical phenomena that are practically more remote.

If we return for a moment to view in its totality the world as conceived by the scientists, we may note that the cardinal fact everywhere is that entities which have become integrated into groups exhibit, as group-entities, new behavior types not elsewhere found. Limitation to biological science seems here to have led M. Bergson and the neo-vitalists astray, for in biology by itself, the fact of levels would appear like a unique happening that, if really unique, would plausibly suggest such mystical forces as the *élan vital,* while seen in the light of other sciences it suggests merely the cardinal fact of naturalistic science. Also the biological conception of evolution is misleading when generalized, for it indicates a one-directional cosmic process building ever toward higher and more complex forms, while in the light of the other sciences it appears as the highly specialized process resultant upon the formation of certain colloidal states of matter and dependent both for its beginning and its close upon the maintenance of such colloids in a proper environment. Inorganic evolution, however, draws no such simple picture, for it, if we are to believe Lockyer, is always accompanied by a devolution for which there is no parallel in the organic world. Instead of the majestic sweep with which Bergson delights our fancy, a truer picture might represent evolution as the history of the formation and life of a bubble on a seething cauldron to the substance of which it must return as new bubbles take its place, and whether or no there is a definite result of the whole boiling is as impossible to predict as it would be to write a man's whole biography from observations made while walking past him on the street. Nor can we find a solution through dialectic, inner need, or intuition. Mill has taught us the futility of dialectic to give us knowledge of physical fact; experience shows a world cold to inner needs, and no intuition can enable us to reconstruct a picture from a shred of the canvas. A *"meditatio generationis futuris,"* however, can only be fruitful close to the range of scientific prediction, minute as compared with cosmic processes, but sufficient to establish a healthy, active morality, though lacking that sanction of an admiring cosmos so ardently sought in morbid or self-doubting civilizations.

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[8] Woodbridge, "The Discovery of the Mind," *Columbia University Quarterly,* December, 1912.

It may be replied, however, as philosophers have often claimed, that the scientific world is not the real world, but to examine this assertion requires a study of the concrete significance of scientific concepts. That study is too difficult to be undertaken in this paper, but will soon follow.

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PERCEPTION AND THINKING

DESCARTES, in the early and somewhat neglected treatise, "Rules for the Direction of the Mind" formulates the problem of knowledge in the following manner. "Now no more useful inquiry can be proposed than that which seeks to determine the nature and the scope of human knowledge..., we first of all divide the whole problem relative to it into two parts; for it ought either to relate to us who are capable of knowledge, or to the things themselves which can be known; and these two factors we discuss separately."[1] Again, "In the matter of cognition of facts two things alone have to be considered, ourselves who know and the objects themselves which are to be known."[2] In these two passages we observe the formulation of the most significant contrast in the domain of modern philosophical analysis. It is a contrast, expressible in many ways, between the knower and the known, between consciousness and its object, between the subjective and the objective, between mind and matter, between man and nature. In our traditional language we say that Descartes is a dualist. This dualism, stated here as a distinction between the knower and the known, and elsewhere emphasized as a dualism of mind and matter, is ultimately reduced by Descartes to a dualism of mechanism and teleology. An empirical observation reveals two entirely different kinds of activity, mechan-

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[1] "The Philosophical Writings of Descartes," Eng. tr., Haldane and Ross, Vol. I., pages 26–27.

[2] *Ibid.*, page 35.